

Searches for Long-Lived Particles at the FCC-ee

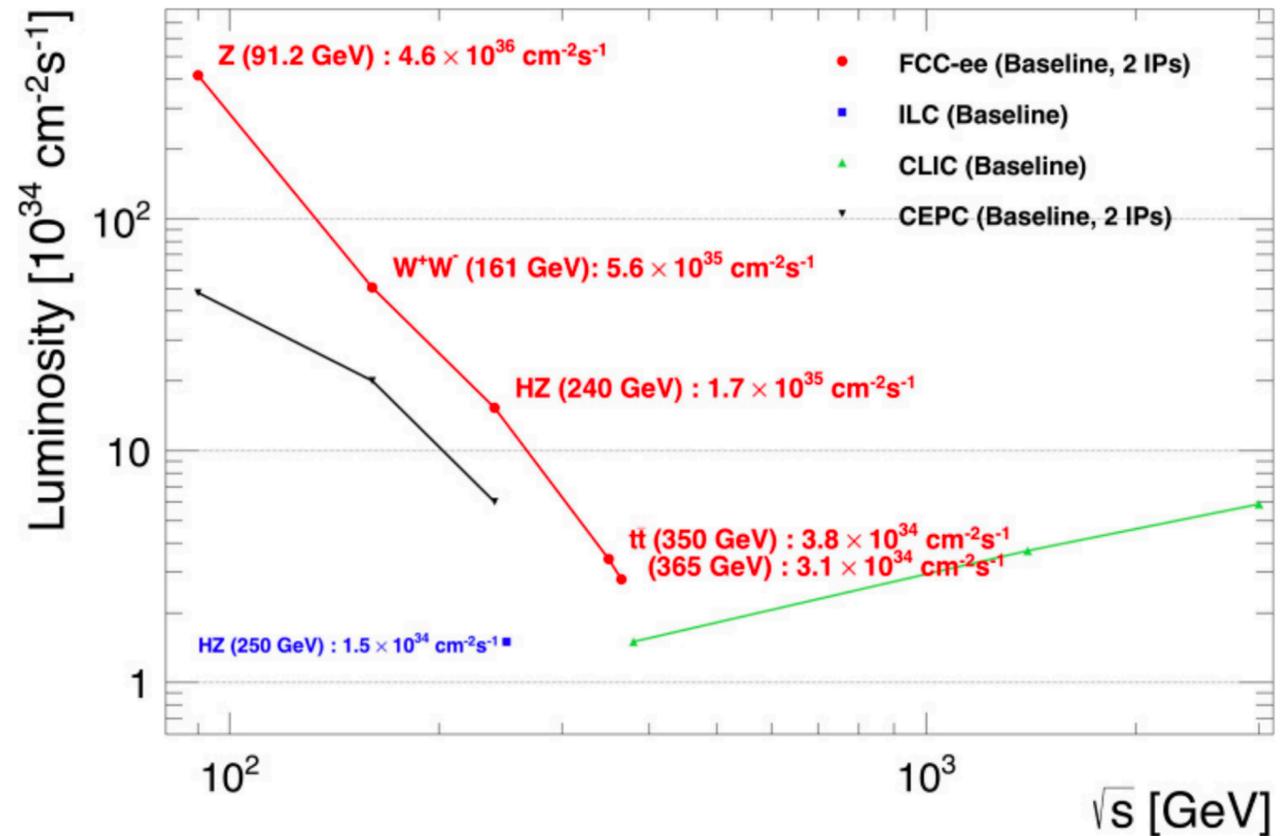
Rebeca Gonzalez Suarez - Uppsala University

A future Electron positron collider

- The updated European Strategy for particle physics recommends an electron-positron Higgs/Electroweak factory as the highest-priority facility after the LHC to be followed up longer term by a very high energy hadron collider.
- The strategy calls for Europe and **its international partners**, to investigate the feasibility of such proposal
- The FCC-ee is an electron-positron collider, and a possible first stage for the FCC-hh Shared infrastructure:
 - 100-kilometer circular tunnel at CERN (passing under the lake Geneva)
 - The FCC-ee tunnel would provide a ready-made home for the FCC-hh (in the same style as LEP and the LHC)
- Beam energies range from about 44 **to 182.5 GeV** covering the Z-pole, W-pair threshold, ZH production and the top-pair production



Energy range

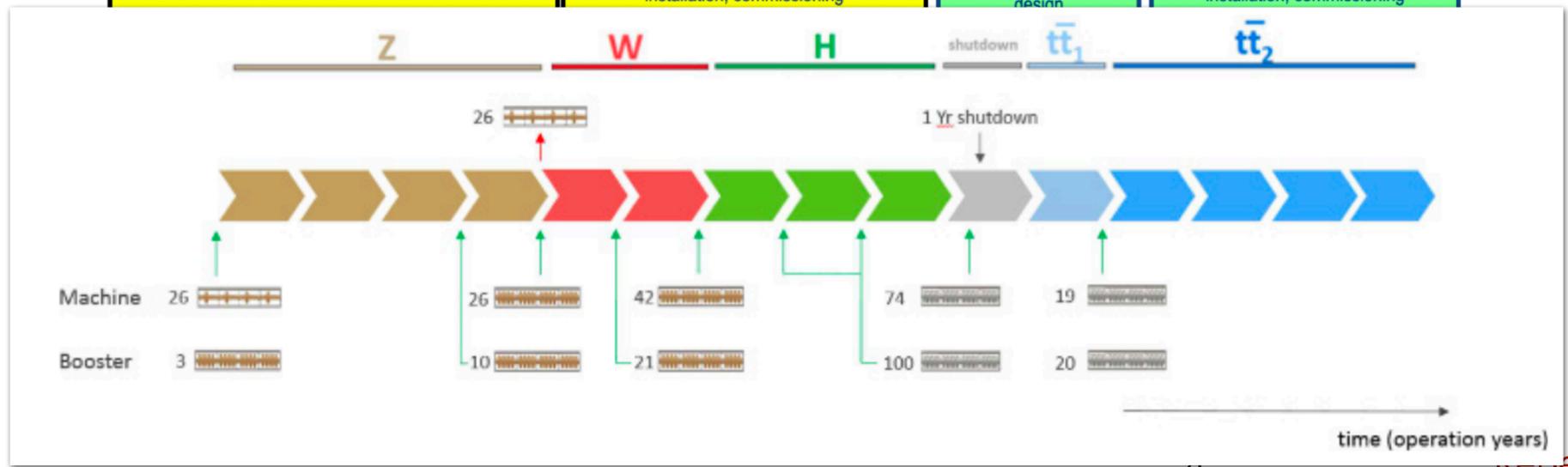
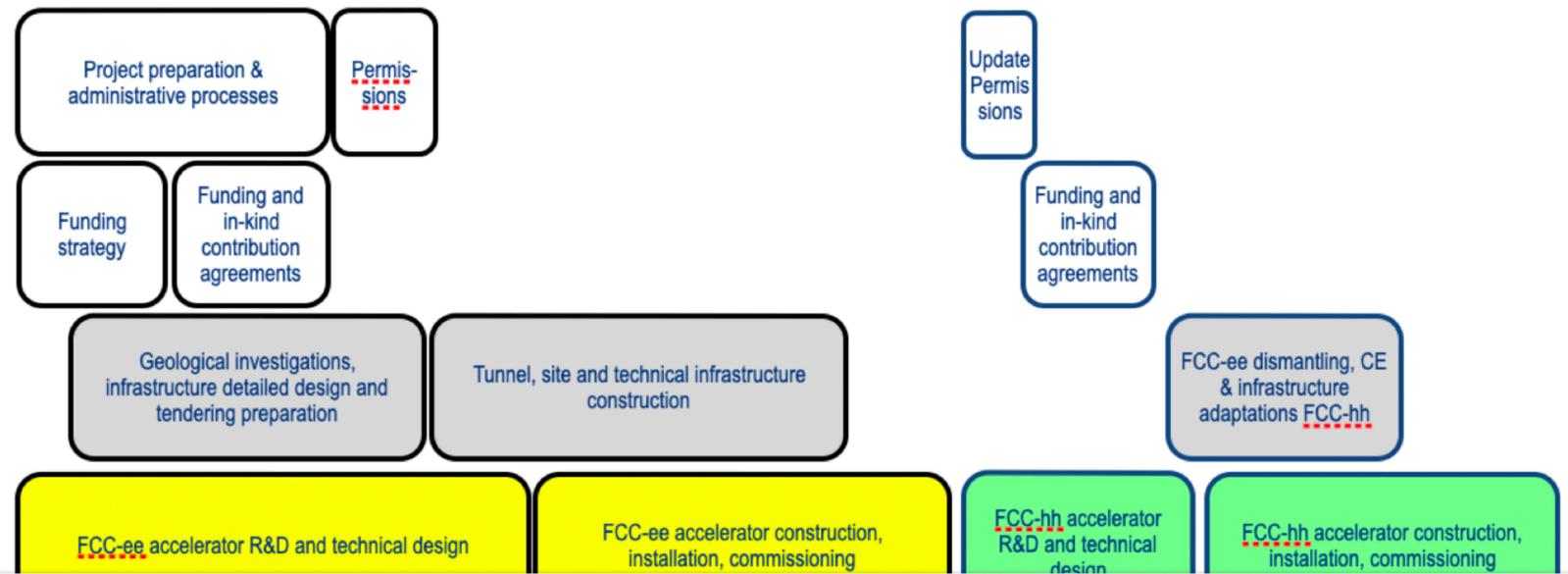
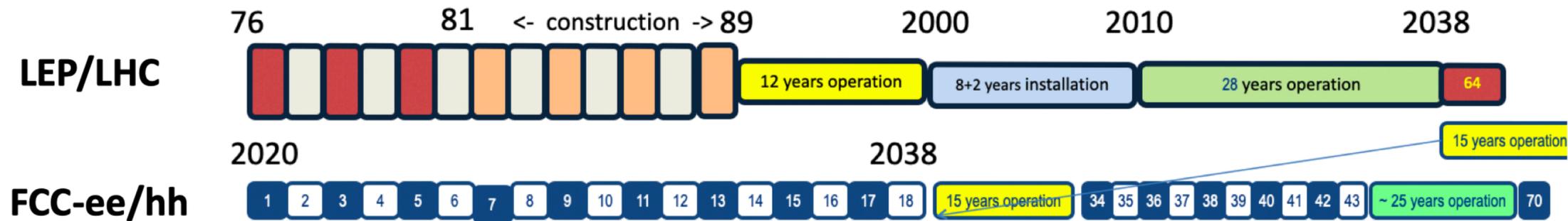


Great energy range for the heavy particles of the Standard Model
Complementarity with hadron (LHC, FCC-hh) and linear colliders

Phase	Run duration (years)	Center-of-mass Energies (GeV)	Integrated Luminosity (ab^{-1})	Event Statistics
FCC-ee-Z	4	88-95	150	3×10^{12} visible Z decays
FCC-ee-W	2	158-162	12	10^8 WW events
FCC-ee-H	3	240	5	10^6 ZH events
FCC-ee-tt	5	345-365	1.5	10^6 $t\bar{t}$ events

LEP x 10^5
LEP x $2 \cdot 10^3$
Never done
Never done

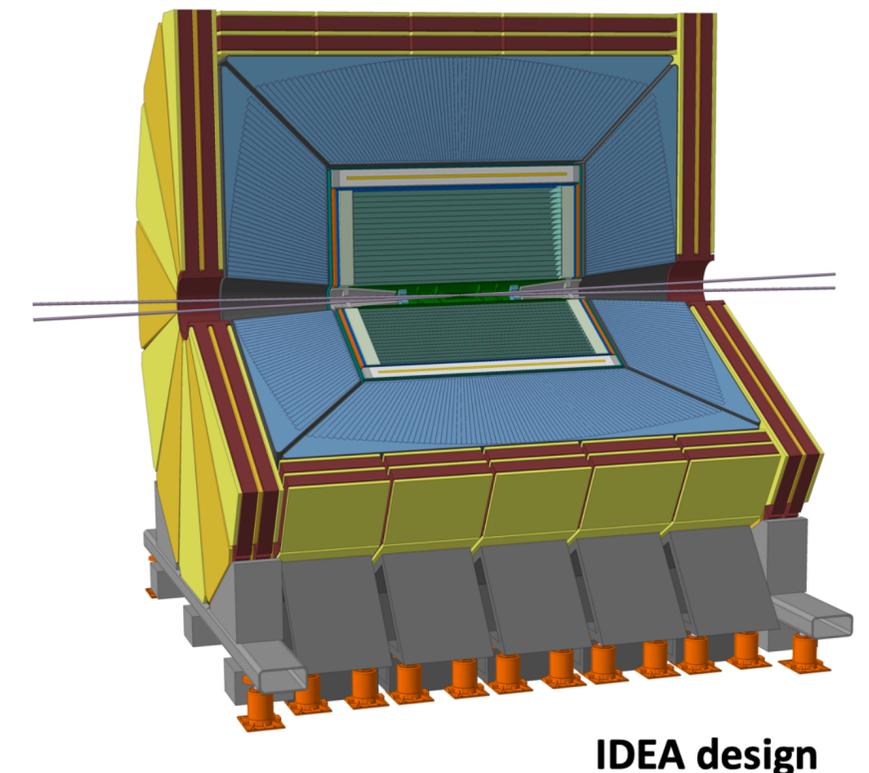
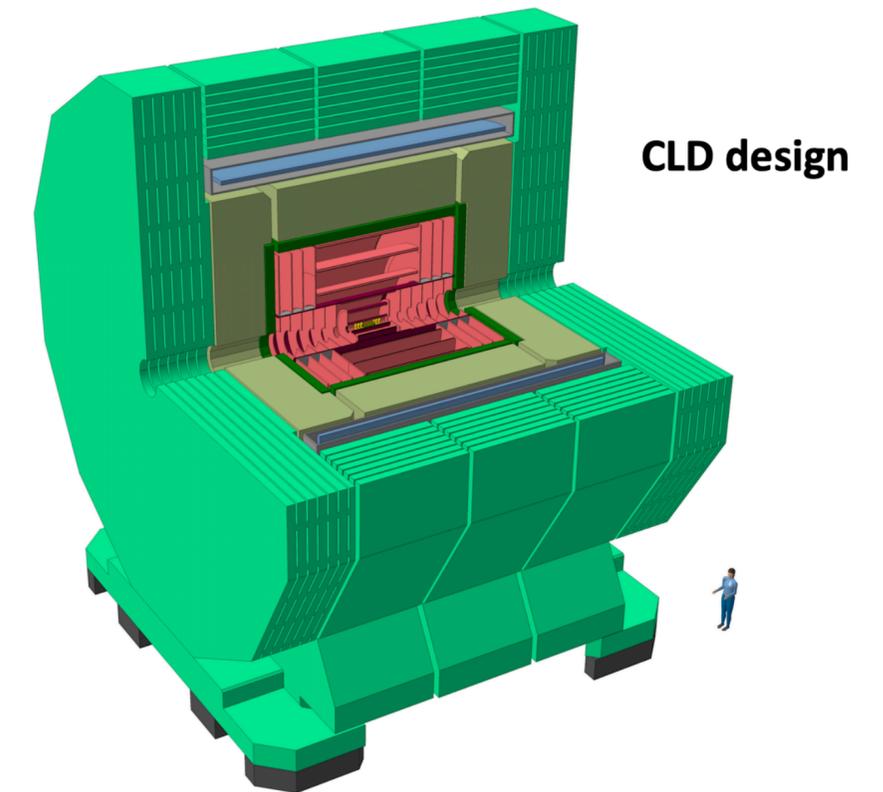
Technical schedule



- The FCC project plan is fully integrated with the HL-LHC and would allow for **seamless continuation** of high energy physics at the energy frontier

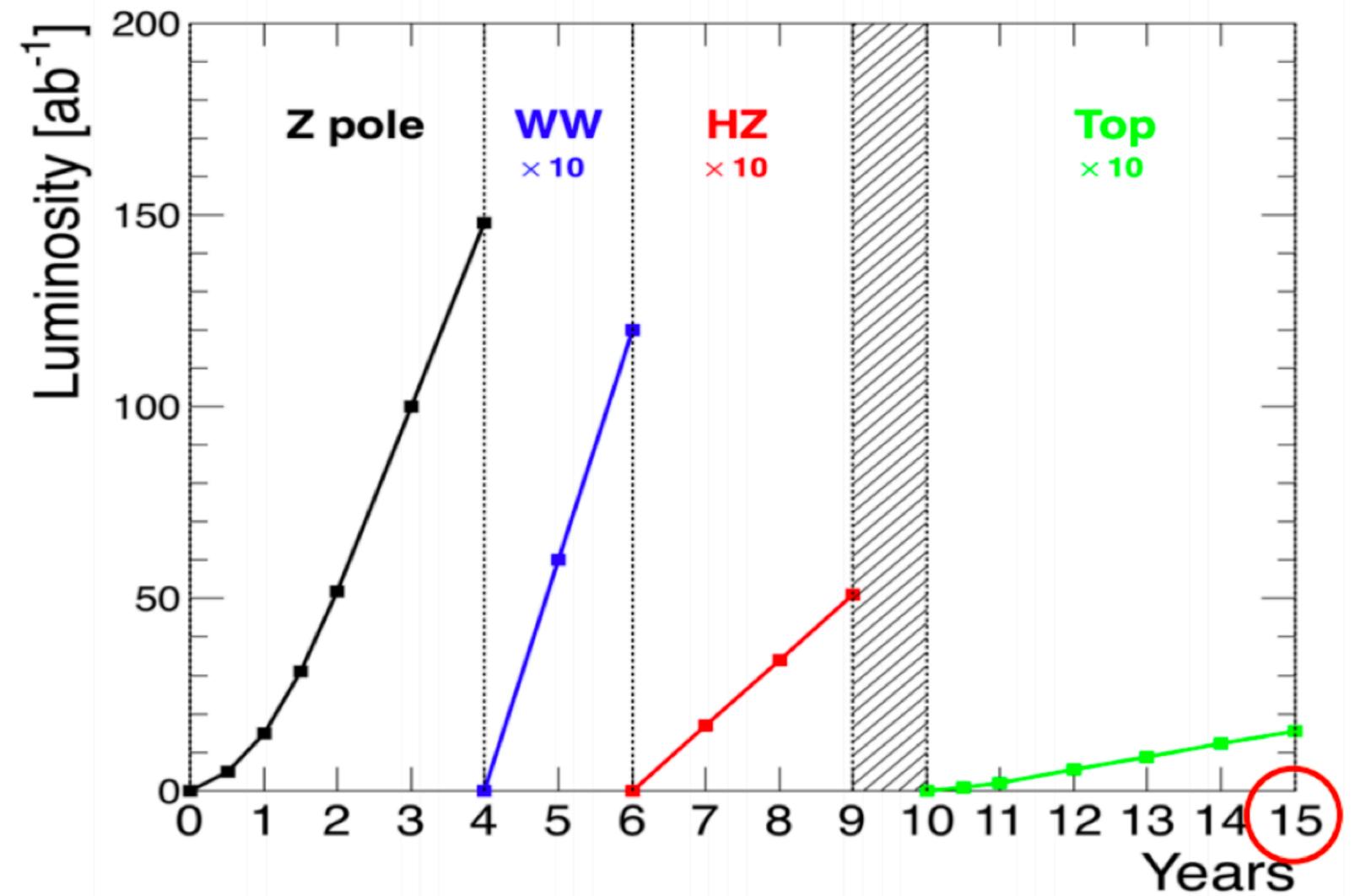
Detectors

- Two detector concepts used for integration, performance, and cost estimates:
 - One adapted for FCC-ee by the Linear Collider Detector group at CERN: CLD
 - One detector specifically designed for FCC-ee (and CEPC): IDEA
- **Now:** we are ready to take a broader look at the physics potential and **optimize detector designs for complete physics program**
- Opportunities to design multiple collider detectors



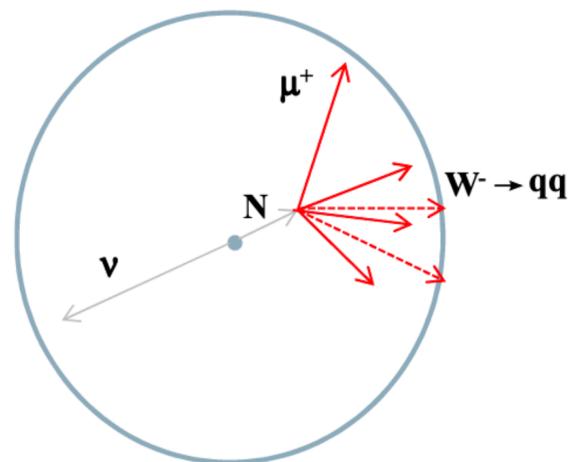
Physics menu

- The FCC-ee is a Higgs factory, but offers substantial additional physics options to explore
 - Higgs factory
 - $10^6 e^+e^- \rightarrow HZ$
 - EW & Top factory
 - $3 \times 10^{12} e^+e^- \rightarrow Z$; $10^8 e^+e^- \rightarrow W^+W^-$
 - $10^6 e^+e^- \rightarrow tt$
 - Flavor factory
 - $5 \times 10^{11} e^+e^- \rightarrow bb, cc$
 - $10^{11} e^+e^- \rightarrow \tau^+\tau^-$
 - Precision tool
 - α_{QED} and α_{QCD} (at m_Z^2), $10^5 H \rightarrow gg$
 - Direct new physics discovery
 - ALPs, RHV's, ...



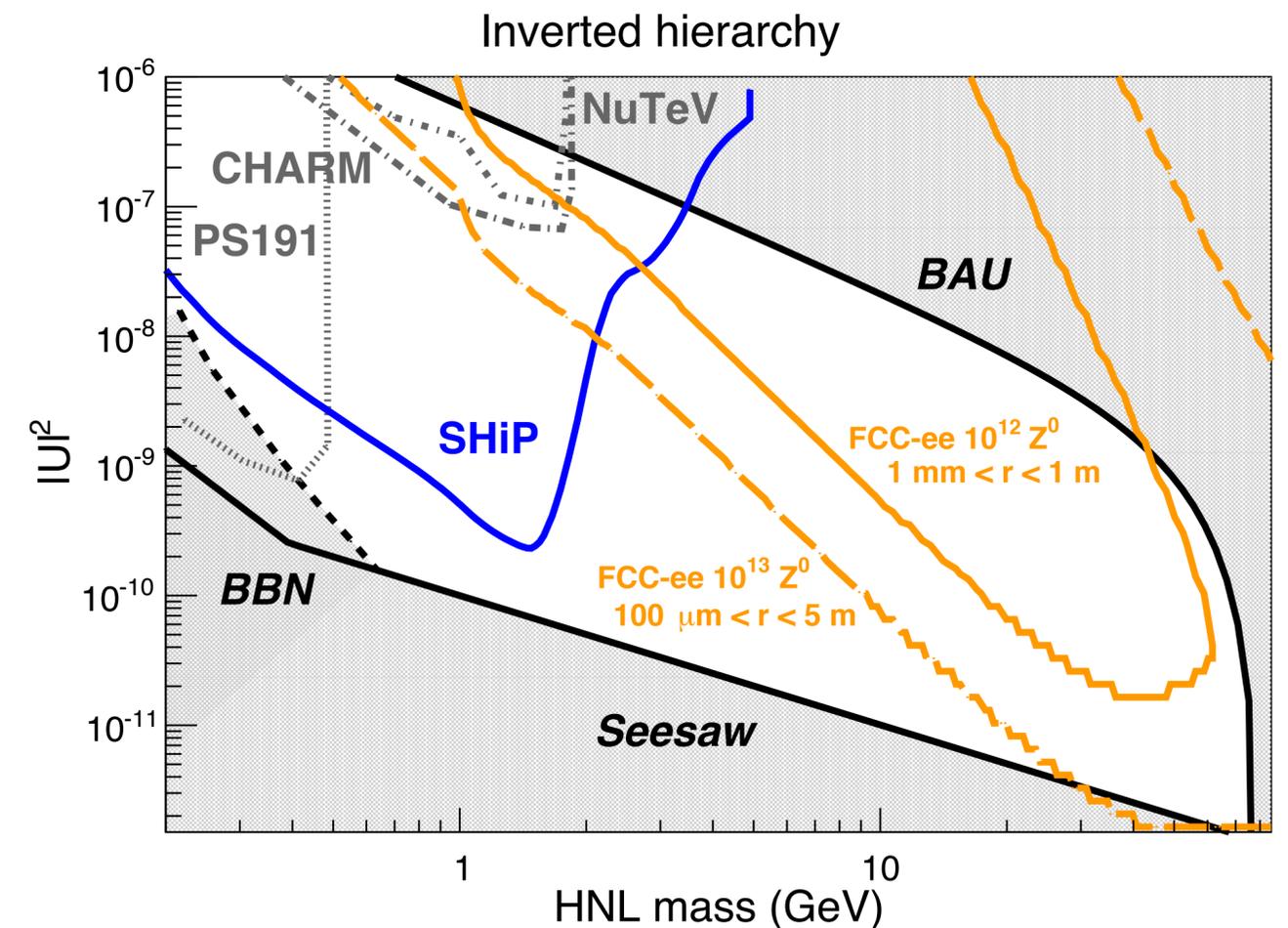
What about long-lived particles?

- There is the possibility for direct searches of new, feebly interacting particles, manifesting long-lived signatures:
 - Answering questions like: Dark Matter, neutrino mass, Baryon Asymmetry of the Universe...
- **FCC-ee Flagship:** Searches for Heavy Neutral Leptons (Right-handed Neutrinos, Heavy Neutrinos...) at the Z-Pole
 - $Z \rightarrow \nu N, N \rightarrow l q \bar{q}$
 - For low values of the neutrino mixing angle, the decay length of the heavy neutrino can be significant



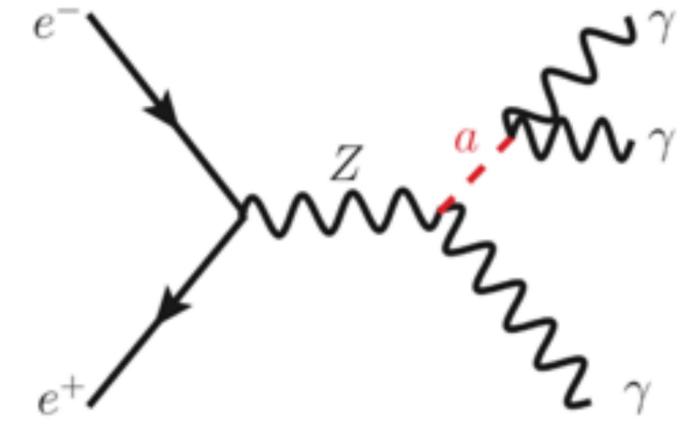
small mixing: long
lifetime, displaced
vertex

arXiv:1411.5230

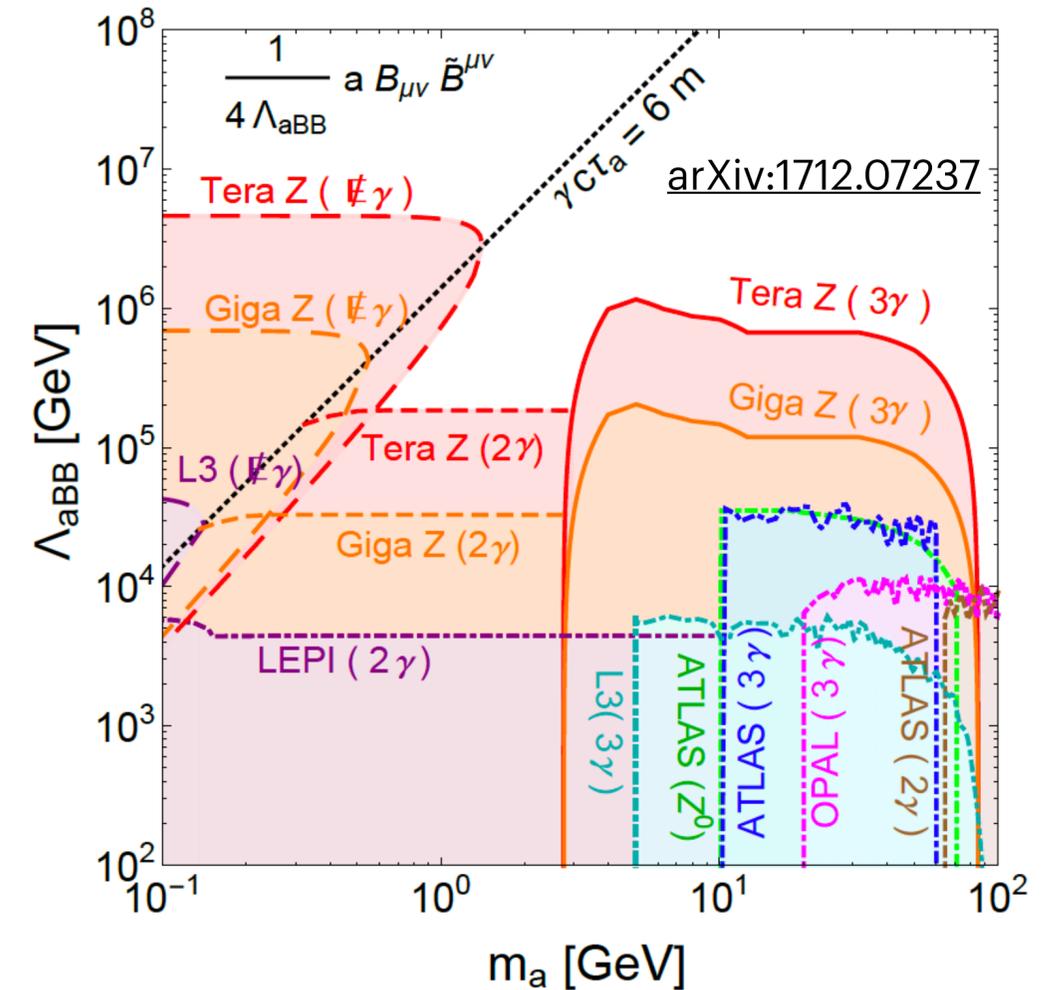
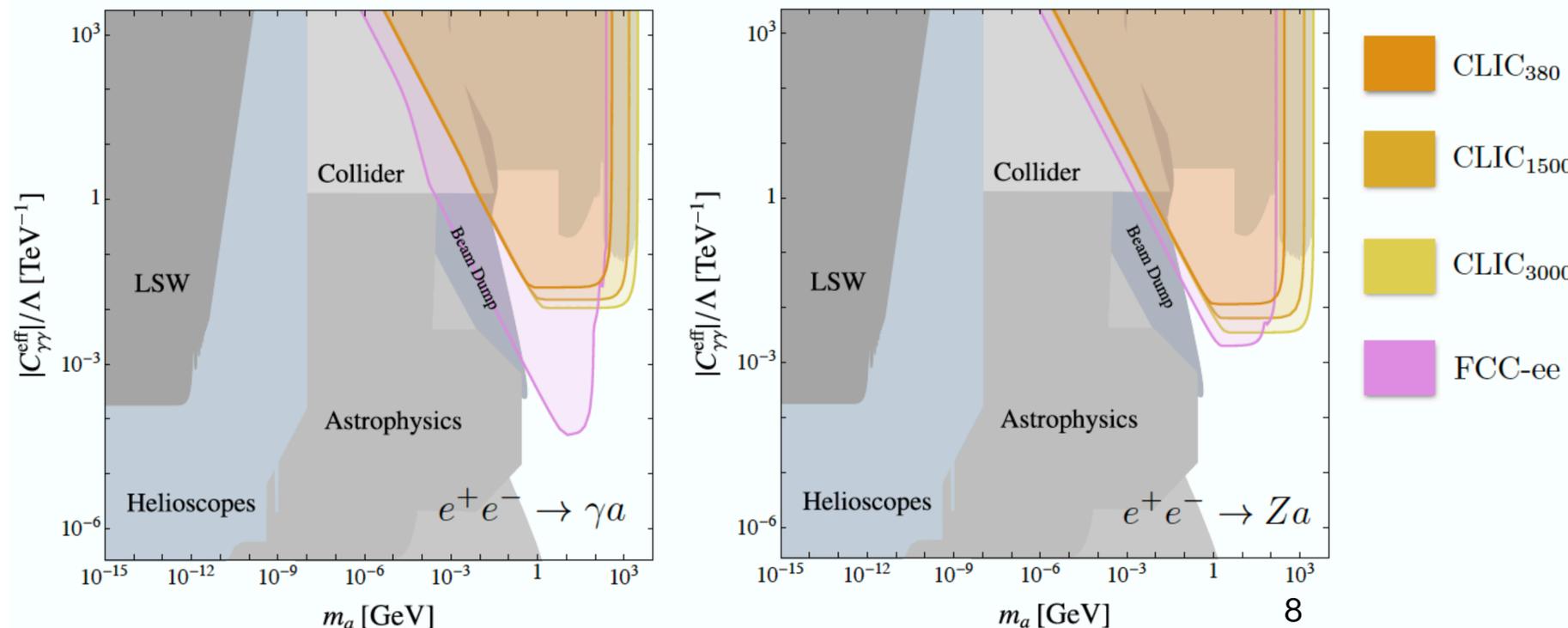


ALPs

- “Axion-Like Particles” (ALPs)
- very-weakly-coupled window to the dark sector
- Specially sensitive final states:
 - $\gamma + \text{MET}$ for very light a
 - $\gamma\gamma$ for light a
 - $\gamma\gamma\gamma$ for heavier a
- Orders of magnitude of parameter space accessible at FCC-ee



arXiv:1808.10323



Beyond HNL and ALPs

- Exotic Higgs
 - Hidden valley ([arXiv:1812.05588](https://arxiv.org/abs/1812.05588))
 - Higgs portal, dark glueball ([arXiv:1911.08721](https://arxiv.org/abs/1911.08721))
 - Neutral naturalness ([arXiv:1506.06141](https://arxiv.org/abs/1506.06141))
- SUSY
 - Folded SUSY ([arXiv:1911.08721](https://arxiv.org/abs/1911.08721))
 - Neutralinos ([arXiv:1904.10661](https://arxiv.org/abs/1904.10661))

Detector-wise

- LLP studies at the FCC-ee offer many experimental opportunities
 - Detector design
 - Tracker size, timing options
 - Reconstruction algorithms
 - Triggers
- Time for creativity

Letter of Interest

- We submitted a letter of interest for Snowmass 2020

Snowmass2021 - Letter of Interest

Searches for Long-Lived Particles at the FCC-ee

Thematic Areas:

- (EF08) BSM: Model specific explorations
- (EF09) BSM: More general explorations
- (EF10) BSM: Dark Matter at colliders
- (RF6) Dark Sector Studies at High Intensities

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Abstract:

The FCC-ee is a frontier Higgs, Top, Electroweak, and Flavour factory. It will be operated in a 100 km circular tunnel built in the CERN area, and will serve as the first step of the FCC integrated programme towards ≥ 100 TeV proton-proton collisions in the same infrastructure¹. In addition to an essential and unique Higgs program, it offers powerful opportunities for discovery of direct or indirect evidence for BSM physics, via a combination of high precision measurements and searches for forbidden or rare processes, and feebly coupled particles.

The direct search for Long Lived particles (LLPs) in the high luminosity Z run, with $5 \cdot 10^{12}$ Z produced, is particularly fertile; high statistics of Higgs, W and top decays in very clean experimental conditions will also be recorded. This motivates an out-of-the-box optimization of the experimental conditions, which is the object of this letter of intent.

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Informal group

- We have made up an informal group and have started having meetings
- Agendas + minutes here:
 - <https://indico.cern.ch/event/962804/>
 - <https://indico.cern.ch/event/966266/>
- We run an equally informal mailing list that you can subscribe to if you are interested (let me know so I can accept you):
 - LLP-FCCee-informal <LLP-FCCee-informal@cern.ch>
- We welcome new people!

Next weeks are filled with events

FCC November week
9-13 November 2020

<https://indico.cern.ch/event/923801/>

4th FCC Physics and Experiments workshop
10-13 November 2020

<https://indico.cern.ch/event/932973/>

Eighth LLP Community workshop
16-19 November 2020

<https://indico.cern.ch/event/922632/>

We are targeting updates in time for these workshops